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DISTRIBUTION OF ACADEMIC RESEARCH FUNDS: CASE OF JAPANESE NATIONAL RESEARCH GRANT

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Distribution of Academic Research Funds: Case of Japanese National Research Grant

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Abstract

Drawing on a database of the competitive research funds in the Japanese academia, this study examines the distribution of research grants at the university and individual levels. The data indicates high inequality at the university level and slightly lower inequality at the individual level. Over the last four decades, the total grant budget has greatly increased and an increasing number of researchers have received the funds. Simultaneously, the average grant size has significantly grown and multiple awarding (i.e., one researcher receives more than one grant at the same time) has become more frequent. These changes being taken together, the level of inequality has not been changed substantially. The extent of inequality largely differs between scientific fields; especially high in basic natural sciences and relatively low in social sciences. A close examination of inequality over researchers' career indicates different patterns of transition between fields and cohorts. Finally, the funding distribution is compared with the distribution of publications as an output indicator, and the former is found more unequal than the latter.

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1. Introduction

Academic research is essentially underpinned by funding from public sources. Research activities in academic institutions, regarded as the foundation of innovation system (e.g., Etzkowitz and Leydesdorff, 2000), have been supported by public funds, but increasing pressure for accountability and tightening budget has urged greater efficiency of funding (Geuna and Martin, 2003; OECD, 1997). From the perspective of individual researchers and academic institutions, stable access to research funds is vital amid the intensifying competition. Consequently, previous literature has discussed various aspects of the funding system, such as peer-review (Kotchen et al., 2004), suitable grant size (Baumeister and Bacharach, 1997), and support for junior researchers (Wadman, 1997). Among others, the equality of funding distribution has been of great interest. Many countries distribute research funds more or less on the basis of the performance of researchers or academic institutions (Geuna and Martin, 2003). Considering the substantial disparity in the performance of researchers (Lotka, 1926), this performance-based funding inevitably results in highly unequal distribution. This funding strategy seems reasonable in that it can provide a direct incentive to improve the output of research. However, such a system could decrease the diversity of research subjects and discourage challenging topics (Geuna and Martin, 2003), compromising scientific progress in the long term. In addition, excessive concentration of funds may be inefficient due to diminishing returns.

To advance this course of argument on funding distribution, funding data has to be deeply analyzed. In actuality, however, funding information is not easily accessible in a comprehensive manner, and most literature on research funding has tended to draw on fairly limited data or focus on qualitative aspects. Importantly, distribution at the individual researcher level has been scarcely studied, while several studies have shown some data on university-level distribution (e.g., Hicks and Katz, 2009). This is a critical pitfall since individual- (or project-) level funding constitutes a significant part of the competitive funding system in many countries. To fill in this gap, this study aims to provide quantitative information on funding distribution, especially giving a focus on the individual level. To this end, I draw on a national grant database in the Japanese academia, which covers the majority of the research grants awarding during the last four decades.

The remainder of this paper is structured as follows. Chapter 2 explains the data and methods of this study with the overview of the funding system in Japanese academia. Chapter 3 briefly describes the university-level funding distribution. Chapter 4 analyzes the individual-level distribution from various perspectives. Chapter 5 compares the distributions of funding and publications. Finally, Chapter 6 summarizes the results and discusses the direction of future research.

2. Data and Methods

2.1. Overview of the funding system in Japanese universities

In Japan, universities are grouped into 86 national universities, 95 other public universities (operated by cities or prefectures), and 597 private universities in 2010 (Figure 1A illustrates the transition of the number of universities). Among these, the national universities are the main player of academic research although several private and public universities are considered research-intensive. For example, national universities account for 71% in terms of the number of Ph.D. graduates,[1] and the primary funding system called Grants-in-Aid for Scientific

[1] Source: School Basic Survey conducted by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT). As of 2009.

Research (the detail is explained later) provides 67% of its total budget for national universities.[2] Among the national universities, the top seven universities (Universities of Tokyo, Kyoto, Tohoku, Osaka, Hokkaido, Kyushu, and Nagoya) have taken the initiative both in research and in education since the late 19th century and obtained especially prestigious status. This section and a part of the following analyses focus on national universities or the top seven universities because of their importance and data availability.[3]

In terms of budgetary structure, the national universities, on average as of 2008, obtained their revenue as block grants from the government (40%), operating income (tuition fees, income from affiliated hospitals if any, etc.) (40%), and competitive funding (20%) (Center for National University Finance and Management, 2010: Ch.14). The first and the second parts are spent largely on salary for faculty members, education, and other operating costs, while the competitive funds play the major role in research activities. In most countries, the revenue of universities consists of organization-level and individual- (or project-) level funds, which is often called a dual-support system (Geuna and Martin, 2003). The organization-level funds are often block grants from governments and are spent on ordinary expenses, while the individual-level funds tend to be used for specific purposes such as research projects. The Japanese system is no exception in this respect.

It is not straightforward to draw a precise picture of the funding structure specifically for research activities because the relation between revenue and expenditure is often unclear. However, a prior study based on an individual-level survey offers a rough picture. Center for National University Finance and Management (2009: Ch.6) shows that individual researchers in national universities obtained their research budget primarily from the governmental competitive

[2] Source: Japan Society for the Promotion of Science (http://www.jsps.go.jp/j-grantsinaid/index.html). As of 2010.
[3] The budgetary and funding structure of private universities is somewhat different from that of national universities. Kneller (2010) also gives an overview of the revenue and expenditure structure of Japanese universities.

funds at the individual (or project) level (65% as of 2007), while a minor part of the budget is supported by their university (20% as of 2007) and industrial funding (5% as of 2007). The budget from universities is basically distributed equally with limited consideration of individual performance. The proportion of each funding source can vary with scientific field; for example, the university budget is more important in social sciences than in natural science. Nevertheless, governmental funds for individual researchers have played the principal role in university research. This emphasis on individual-level funds has been strengthened since the 1960s (Center for National University Finance and Management, 2009: Ch.6).

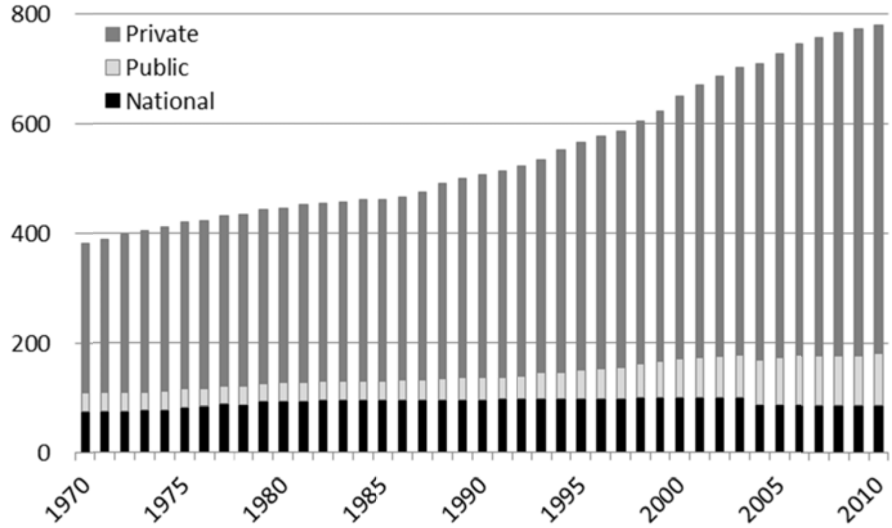
There are numerous types of governmental research funding systems, but among others, Grants-in-Aid for Scientific Research (GIA, hereafter) have been playing the most fundamental role. GIA is the largest funding system, covering all scientific fields from social sciences to natural sciences, and is broadly awarded to university researchers from Ph.D. students to full professors.[4] The system of GIA dates back to the 1950s. Since then, the budget of GIA has been consistently increased in an attempt to improve the capability of university research, and it amounted to 200 billion JPY (2.2 billion USD) in 2010 (Figure 1C). Until the 1980s, GIA had been virtually the only individual-level funds (Center for National University Finance and Management, 2009: Ch.6). Afterwards, the government has implemented many funding systems for various objectives.[5] Nevertheless, GIA accounts for the majority of all the competitive funding (National Institute of Science and Technology Policy, 2009), and its role as the primary research funds has unchanged. For this central role in academic research and the availability of data, this study focuses on the distribution of GIA.

[4] The general information of GIA is given in the MEXT website (http://www.mext.go.jp/a_menu/shinkou/hojyo/main5_a5.htm).

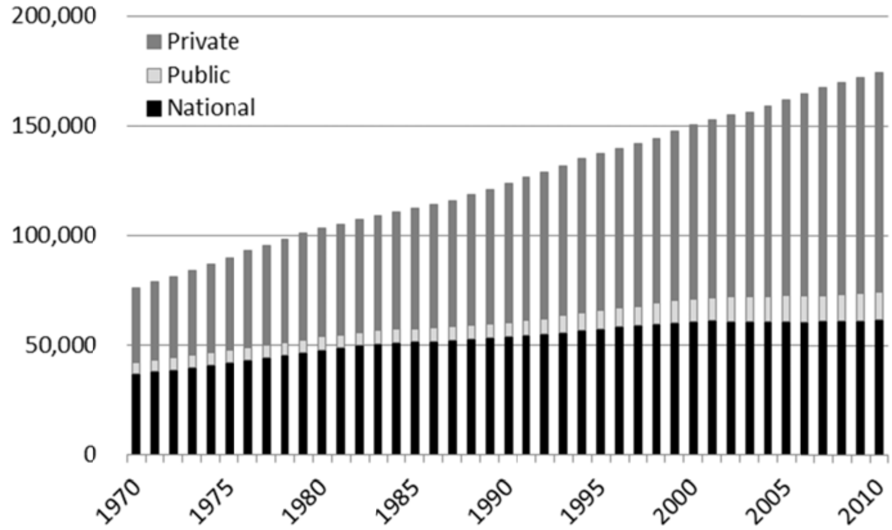
[5] As of 2008, there are 44 competitive funding systems. Some of them are individual-level funds for university research, but others are awarded to institutions, primarily focus on industrial research, or aim at education.

Figure 1 Growth of university system [6]

(A) Number of universities



(B) Number of faculty members



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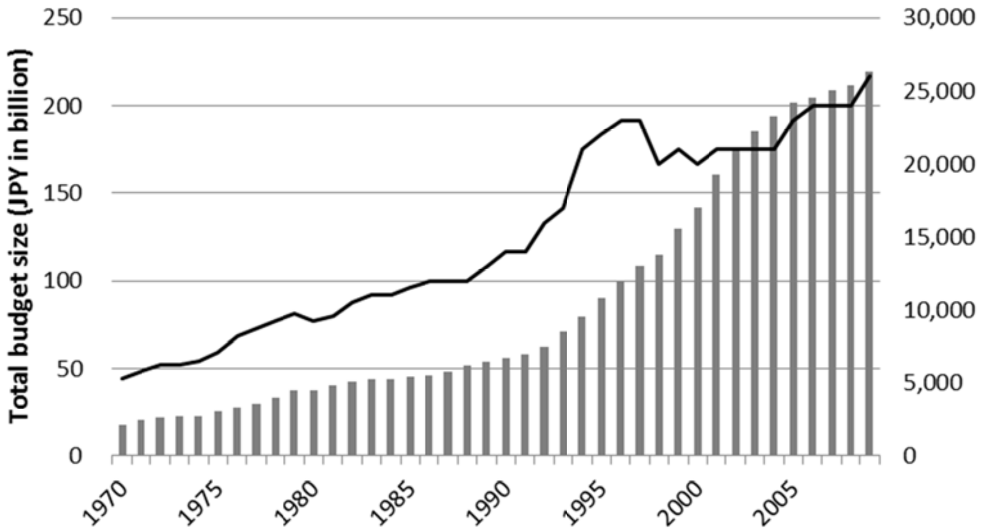
[6] (A) and (B) Source: School Basic Survey conducted by MEXT. (C) Source: The white papers of MEXT. The price level is adjusted by the GDP deflator (the base year is 2000).

(C) Grants-in-Aid for Scientific Research



2.2. Data source

The grant information for GIA is available through a public database.[7] The database provides the information of research project supported by GIA since 1965; such as grant amount, researchers involved in the project, a grant category, a scientific field, resulting publications, and so forth. I obtained the whole dataset as of December 3, 2008 and reconstructed it for this study. The final dataset includes approximately 600,000 grants and 210,000 researchers.

In the analysis of funding distribution at the individual level, it is necessary to know the number of all researchers. In this respect, an obvious limitation of the database is that it does not include non-grantees. In fact, university faculty members receiving no GIA grant tend to be non-researchers (e.g., teaching staff), but there can be exceptions (e.g., researchers who need very limited amount of research funds). To address this issue, I also draw on national statistics

[7] The original data can be obtained from the website of the National institute of informatics (http://kaken.nii.ac.jp/en/).

covering all university faculty members (Figure 1B). However, there is another problem that the statistics do not distinguish faculty members who actually do research and those who mainly engage in non-research missions. Thus, simply taking the number of faculty members would overestimate the inequality due to those who do not research. This problem is less serious for national universities than for private universities, and is even limited for top universities. The majority of faculty members in top universities actually engage in research activities and obtain the grants.[8] On the other hand, many faculty members in private universities are teachers. To mitigate this issue, I draw on a few different sets of university population and researcher population in the following analyses.

2.3. Gini coefficient

In order to quantify the funding distribution, I use the Gini coefficient as an indicator of inequality. It is a simple measure ranging from zero (when everyone takes the same amount) to one (when one takes all). The Gini coefficient has been commonly used in scientometric research (e.g., Burrell, 1991; Zitt et al., 1999). It has several advantageous features such as scale independence (the total amount of grant does not matter) and population independence (the number of universities or researchers does not matter) (Ray, 1998). Mathematically, the Gini coefficient is defined as the ratio of *the area between the line of equality and the Lorenz curve* divided by *the total area under the line of equality*, where the Lorenz curve shows the percentage of the total wealth given to the bottom x% of entities (Dorfman, 1979) (see Figure 2B). To calculate Gini coefficients for the funding distribution, I use the following equation (Halffman and Leydesdorff, 2010):

[8] I examined the ratio of grantees in all full and associate professors in the University of Tokyo (ranked first). After excluding those who have no publication, part-time employees (many of them are from industry), and apparent non-researchers, 95% or more of professors have obtained the GIA grants regardless of scientific fields.

$$\text{Gini Coefficient} = \frac{\sum_{i=1}^{n}(2i - n - 1)y_i}{n\sum_{i=1}^{n} y_i}$$

, where n denotes the total number of researchers or universities and y_i (i=1 to n; $y_i \le y_{i+1}$) denotes the amount of the grant awarded to the ith researcher or university.

3. University Level Distribution

First, I examine the university-level funding distribution. Figure 2A illustrates the share of the top 20 and the rest of the Japanese universities in 2005. I calculated the grant amount of each university by summing up the grants awarded to principal investigators (PIs)[9] affiliated with the university. Among all 726 universities, 218 universities received no grants, most of which are private schools. The pie chart indicates that the top university took 15% of the total amount and that the top seven universities accounted for 50%. The top 20 universities took nearly 70%, while the rest of 30% was distributed to the rest of hundreds of universities.

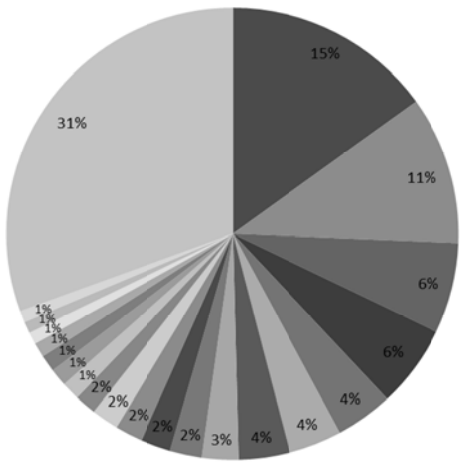
Figure 2B shows the Lorenz curves of the university-level funding distribution in 2005. It clearly shows a highly unequal distribution with a Gini coefficient of 0.919. I also examined the transition of the Gini coefficients and found that the extent of inequality has not noticeably changed over 40 years (0.900 in 1995, 0.899 in 1985, and 0.914 in 1975). As mentioned above, many private universities are not research oriented, and the number of private universities has significantly increased in the periods (Figure 1A). This might have raised the Gini coefficients in recent years, so I also calculated Gini coefficients only for national universities, which have constantly received more than 80% of the total budget. The Gini coefficients of each year are

[9] A principal investigator (PI) is the researcher who supervises a certain project. In most projects, there is only one PI, but for large projects, there are sometimes more than one PI. In such cases, grant amount is divided by the number of PIs to calculate the per-PI amount.

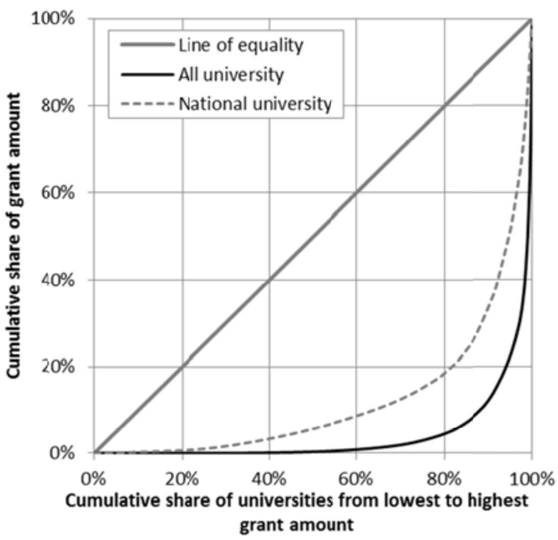
0.760 in 2005, 0.787 in 1995, 0.788 in 1985, and 0.754 in 1975, which also indicates limited change during the four decades.

Figure 2 Grant share at the university level in 2005

(A) Share of the top 20 universities and the rest



(B) Lorenz curve for the grant share of universities



4. Individual Level Distribution

4.1. Multiple awarding and large grants

Next, I examine the individual-level funding distribution. The individual-level inequality of grant distribution has been intensely discussed for years in Japan. Apart from the overall inequality, two issues have been of specific interest: (1) the size of some grants may be excessively large, and (2) some researchers obtain too many grants simultaneously (Council for Science and Technology, 2008).

For the former issue, I examine the transition of grant size since the 1970s. Figure 3A shows the proportions of three size groups: large (greater than 100 million JPY), middle (10 – 100 million JPY), and small (less than 10 million JPY). The graph clearly indicates a tendency to enrich larger grants. For example, in 1971-1975, small-size grants account for 76% and middle-size grants account for 24%, whereas small size is only 32% but middle size is 46% and large size is 21% in 2001-2005. Noticeably, since the 1990s, large-size grants have constituted about 20% of total budget. However, the recent two periods show a slight decrease in the proportion of large grants (from 23% in 1996-2000 to 21% in 2001-2005), although the budget amount for large-size grants have increased by 35%. This may reflect the revision of governmental funding policy to suppress the criticisms on excessively large grants.[10]

For the second issue, one researcher can apply for and obtain more than one grant simultaneously although there are some restrictions on such multiple awarding. This issue has aroused criticism in other nations (e.g., Hand, 2008). A typical argument against multiple awarding is that researchers can devote only limited efforts to each granted project, which compromises the efficiency of the fund use. In addition, when multiple awarding is allowed,

[10] In fact, the government mentions that the average grant size has been decreasing since 2002 (http://www.mext.go.jp/a_menu/shinkou/hojyo/1289168.htm).

researchers are incentivized to apply for many grants, which inevitably increases the time for grant application and decreases the time for actual research. To scrutinize this issue, I counted the number of grants that each researcher received as a PI simultaneously in a single year (Figure 3B).[11] I considered only full and associate professors in this analysis because other junior researchers are unlikely to receive multiple grants.[12] The graph shows that most researchers obtained only one grant but 10-20% received two or more grants simultaneously.[13] The ratio of multiple awarding increased from 9% in 1975 to 21% in 1995, and has slightly decreased to 16% in 2005. This seems to address the criticism on multiple awarding, but the number of such incidents has actually slightly increased. In addition, when both PIs and non-PI members are considered, 42% researchers were involved in more than one project in 2005. The maximum number of multiple awarding to a single PI was seven and that to a single PI or member was 27 in 2005.

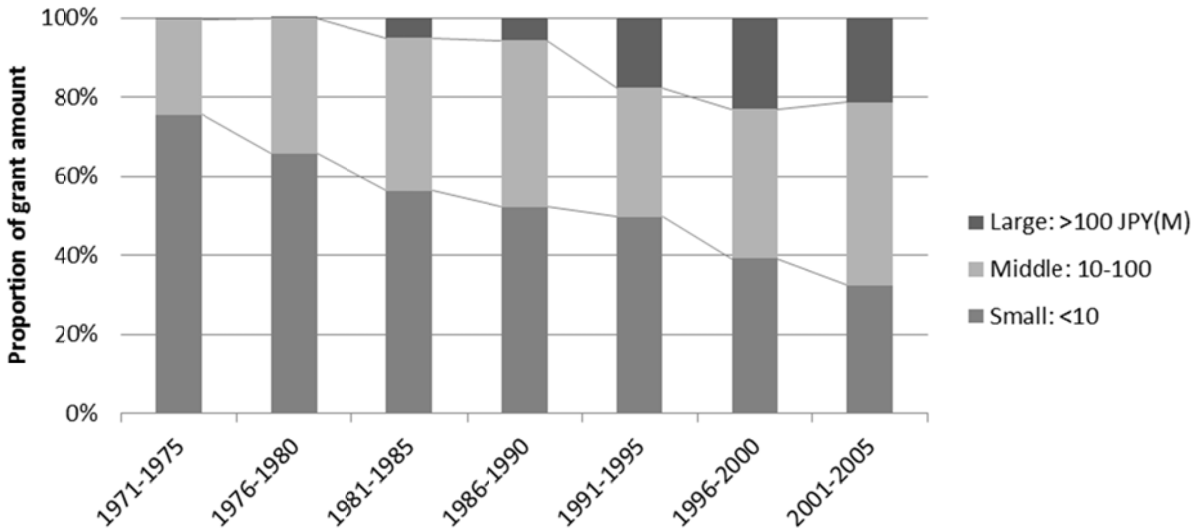
[11] I included all grants whose grant term includes either 1995 or 2005. For example, if a researcher received one grant from 1993 to 1995 and another grant from 1995 to 1997, this researcher is regarded as a multiple awardee in 1995.

[12] In Japan, typical laboratories consist of one full professor, one associate professor, a few junior staff (assistant professors, postdoctoral researchers, etc.), and students, where full and associate professors control the management of the laboratory and often secure research funds for other staff.

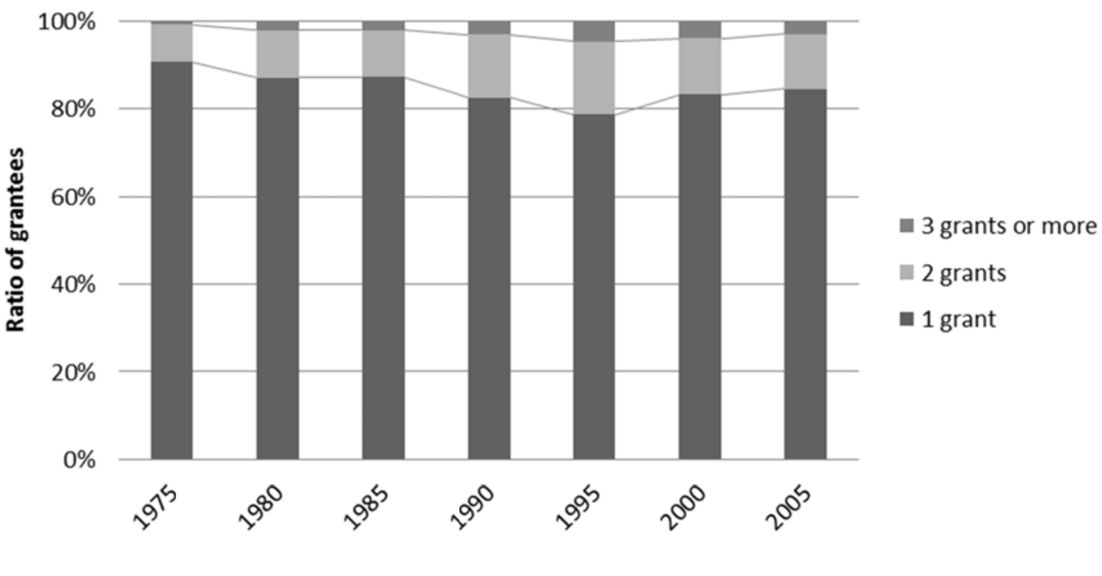
[13] In 2005, approximately 4,000 full and associate professors receive two or more grants as a PI, which accounts for 16% of all the professors who receive at least one grant in the year. When all professors in all universities are considered (which include non-researchers), the ratio drops to 5.4%. When focusing on the top seven universities, about 2,000 professors were multiple awardees in 2005, which accounts for 17% of all professors in the universities.

Figure 3 Grant size and multiple awarding [14]

(A) Grant size



(B) Multiple awarding



[14] (A) I summed up the grant amount during five years for each size group. The price level is adjusted by the GDP deflator (the base year is 2000). (B) Only full and associate professors are considered.

4.2. Inequality of distribution

To examine the overall distribution, I calculate the Gini coefficient at the individual level. As mentioned above, a problem in this analysis is that the true number of "researchers" is not known. To mitigate this restriction, I draw on two different populations. The first analysis is based on the assumption that all "researchers" receive the GIA grant at least once in a sufficiently long period.[15] Put differently, faculty members who do not receive any grant in the term are regarded as a non-researcher. This assumption may be too simplistic but still reasonable in that GIA is the primary funds for university research and that most faculty members in research-intensive universities are actually awarded the grant. Nevertheless, Gini coefficients obtained in this way can be underestimation due to the potential exclusion of actual researchers who happened not to receive any grant in a specific term. The second population focuses on the top seven universities. The seven universities have constantly obtained approximately 50% of the GIA grants. The number of faculty members in the seven universities account for 30% of those in all national universities and 11% of all universities. Based on the assumption that most faculty members in these universities are researchers, I use the number of faculty members reported by each university. This calculation has an advantage of including researchers who happened to receive no grant in a certain term, but it can include a certain number of non-researchers, resulting in overestimation of inequality.

Figure 4A describes Lorenz curves for the two above-mentioned populations. In this analysis, I focus on full and associate professors because other junior researchers are institutionally awarded only limited amount of grants. The Gini coefficients are 0.685 (all

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[15] I use five years in the following analysis. The government regards five years as a standard term of research. The acceptance rate of GIA has been approximately 25%, so most applicants are supposed to receive at least one grant in five years if multiple awarding is sufficiently limited.

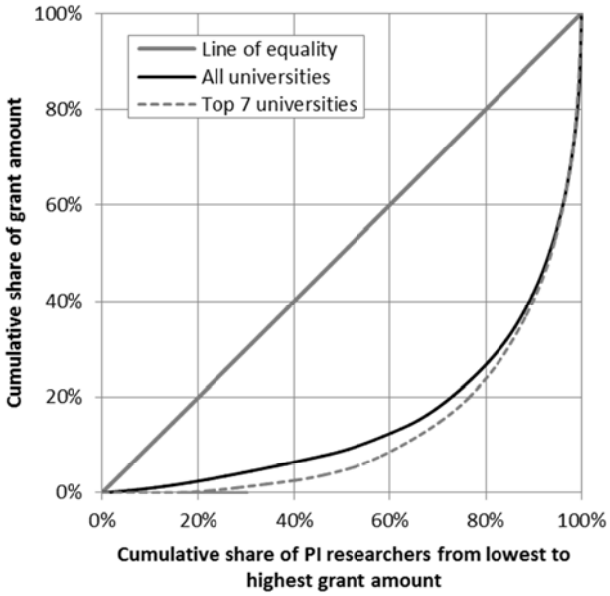
universities) and 0.736 (top seven universities) in 2001-2005.[16] Figure 4B illustrates the transition of the inequality since the 1970s. The two lines are more or less stable around 0.70 and 0.75 respectively over the four decades, but the inequality seems to have increased in the 1970s and the 1980s and then decreased in the 1990s and the 2000s. The slight decrease in the recent decade might be related to the governmental policy to suppress inequality.

Since grant size greatly differs by scientific fields, I also examine the funding distribution by field. On the basis of the research areas of faculty members, I divided all researchers into five groups of fields.[17] Figure 4C reveals a difference of inequality between fields. The lowest inequality is found in social sciences (Gini coefficient = 0.595). Compared to this, the four natural science fields show higher inequality. This is possibly because the size of grants in social sciences tends to be smaller than that in natural sciences. Among natural sciences, basic biology is the most unequal (Gini coefficient = 0.728). Mathematics and physics shows the second highest inequality (0.726), and the other two fields have relatively low inequality (engineering and chemistry: 0.664 and applied biology: 0.649). Thus, the grant distribution in basic research seems more unequal than that in applied research.

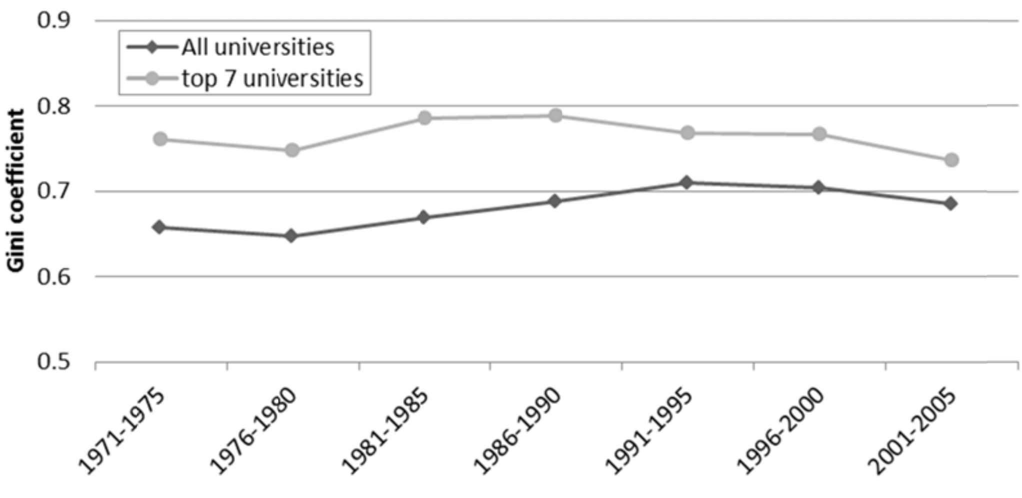
[16] For the top seven universities, faculty members who received no grant are taken into account. They account for 16% of all faculty members in 2001-2005. On the other hand, for all universities non-grantees are ignored. Note that this different definition of population results in larger inequality in the top seven universities than in all universities.
[17] The field of each researcher is determined on the basis of the field most frequently assigned to their past grants.

Figure 4 Grant share at the individual level [18]

(A) Lorenz curve of the grant share of individual researchers in 2001-2005

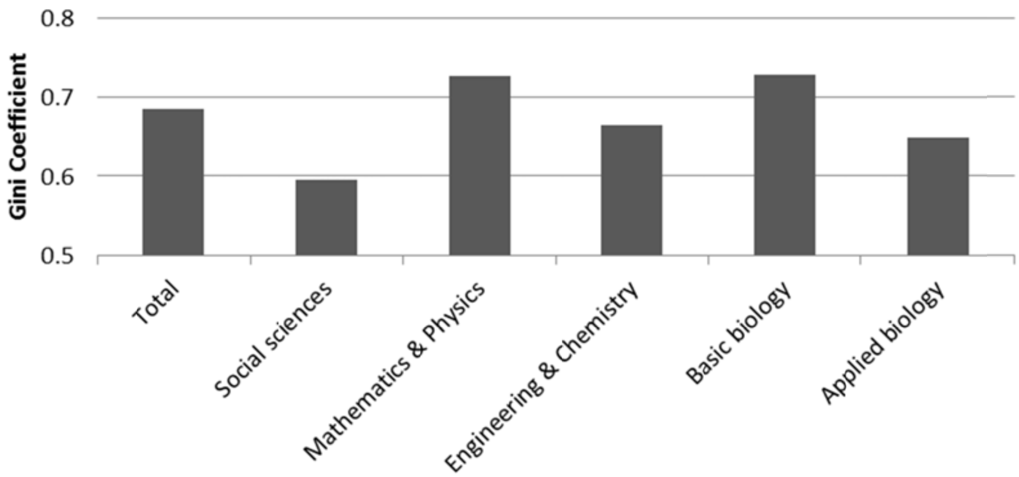


(B) Transition of inequality



[18] (A) and (B) For the two populations, all the grants awarded to each individual in five years are summed up. Each grant amount is divided by the number of PIs if more than one PI is assigned to one grant. Only full and associate professors are considered. (C) The first population (all universities) is used.

(C) Inequality by field in 2001-2005



4.3. Transition of inequality across cohorts and over careers

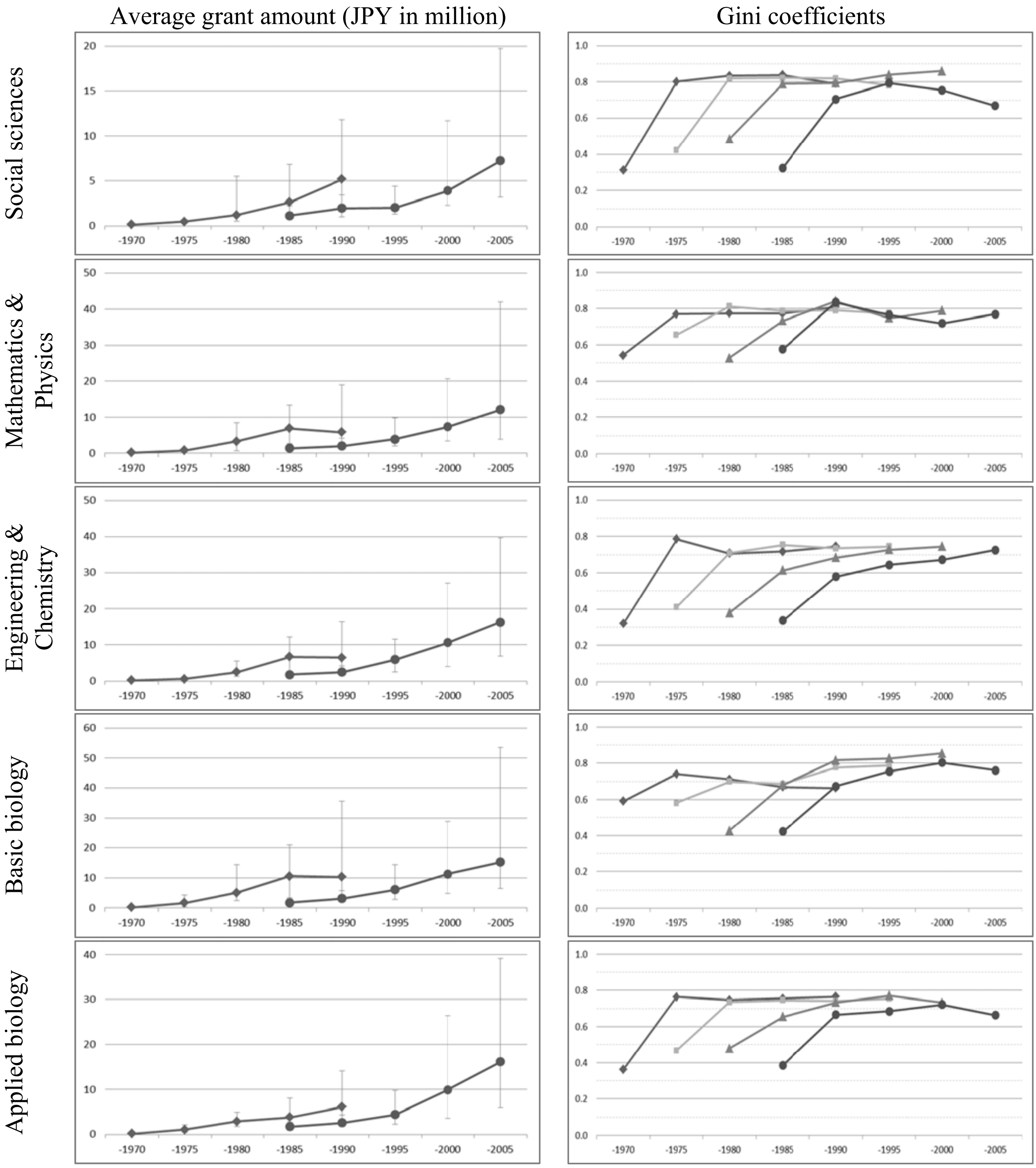
Next, I investigate the transition of inequality over researcher's career with controlling the cohort. The limitation of the analysis in the previous sections is that the population of researchers includes both less experienced researchers and more experienced researchers, whose fund sizes may well be different. Thus, I examine inequality focusing on four cohorts of researchers who started their career in (1) 1966-1970, (2) 1971-1975, (3) 1976-1980, and (4) 1981-1985. Then, I followed the transition of inequality in each cohort over 25 years.[19] The left column of Figure 5 shows the transition of average grant sizes for cohorts 1 and 4, while the right column illustrates the transition of Gini coefficients for the four cohorts.

The left column indicates a growing size and inequality for both cohorts 1 and 4 in five field. Although the growth of the average size is not drastic, the deviation shown by the error

[19] I chose the researchers who have 25 or more years of career (the latest grant-awarded year minus the earliest year is 25 or more) and whose first grant was given when they were an assistant or post-doctoral researcher. Put differently, I excluded researchers whose career ends before 25 years; such as those moved to industry or teaching universities. If these researchers were included, the inequality in later career stages would be higher.

bars (25 and 75 percentiles) increases quickly as a career advances. When the two cohorts are compared, both the average grant size and the deviation are found larger in cohort 4 than in cohort 1 in all fields. These appear to imply increasing inequality over the career and over the generations, but this is not obvious because the total funding amount has grown simultaneously (Figure 1C). With this regard, the Gini coefficient is a useful indicator of inequality because it is scale-free. The right column of Figure 5 indicates increasing inequality in all fields and in all cohorts with a few exceptions (such as cohort 4 in social sciences). This suggests that researchers are given relatively equal opportunity in their junior stage, and that winners in the stage take major resources in the subsequent stages. When comparing inequality between cohorts, the inequality at the final career stage shows similar levels between cohorts. On the other hand, the inequality at the first stage varies largely with the field and cohort. While social sciences, engineering and chemistry, and applied biology show relatively low inequality (around 0.4) at the first stage, mathematics and physics indicate high inequality (around 0.6) from the beginning. Interestingly, basic biology had a high inequality (around 0.6) at the first stage in cohorts 1 and 2, but it largely decreased in cohorts 3 and 4 (around 0.4). This may suggest that the field of basic biology had come to place a greater emphasis on equal opportunity at the junior stage. Looking into the transition over the career, social sciences and mathematics and physics quickly rise to their maximum inequality. Especially, in social sciences, although junior-stage inequality is relatively low, it reaches 0.7 - 0.8 in five years. This may suggest that performance at the very beginning is critical for the later career in the field.

Figure 5 Transition of grant distribution across cohorts and over career [20]



[20] The left column indicates the median grant amount (total in five years) for two cohorts whose career started during 1966-1970 and 1981-1985. Error bars indicate 25 and 75 percentile amounts. The scales of vertical axes differ between fields. The right column shows the transition of Gini coefficients over the career in the four cohorts whose career started during 1966-1970, 1971-1975, 1976-1980, and 1981-1985, respectively.

5. Inequality in Output

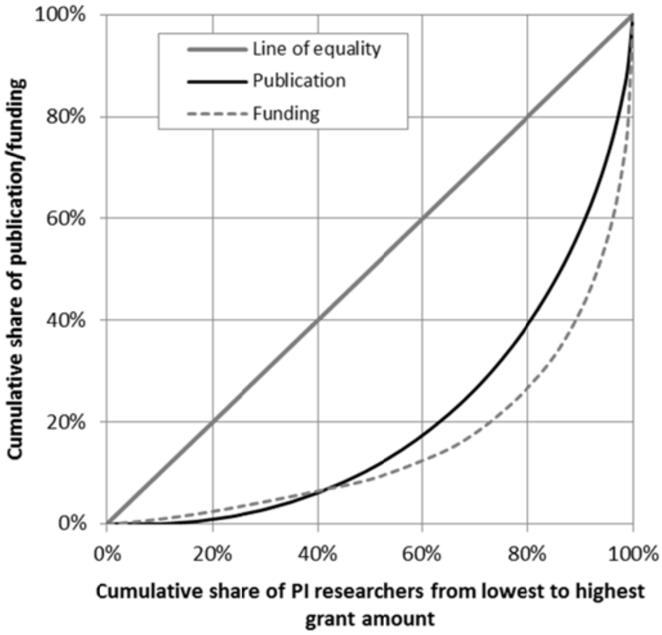
To consider the efficiency of funding distribution, I also examine the distribution of output in terms of the number publications. The grant database archives the reports of each granted project, which list the publications from the project. First, I counted the number of publications in each university, whereby the Gini coefficient is calculated. In 2005, the coefficient for all universities is 0.845, which is slightly smaller than that for funding distribution, or 0.919. I also focus on national universities and compare the inequality. The Gini coefficient for the publication distribution is 0.676, while that for funding is 0.760.[21]

Furthermore, I compare the individual-level distributions of funding and publications. The Gini coefficient for the publications of full and associate professors in all universities in 2001-2005 is 0.592, which is smaller than that for funding, or 0.685 (Figure 6A). I also focus on the top seven universities, which indicates the Gini coefficient of 0.632 for publication and 0.736 for funding. Finally, I compare the two distributions in each scientific field. Figure 6B indicates that publication inequality is smaller than funding inequality in all fields except for social sciences. The difference is especially noteworthy in mathematics and physics (0.523 vs. 0.726) and basic biology (0.570 vs. 0.728). Overall, the greater inequality in funding than in publication seems to imply an excessive concentration of funding.

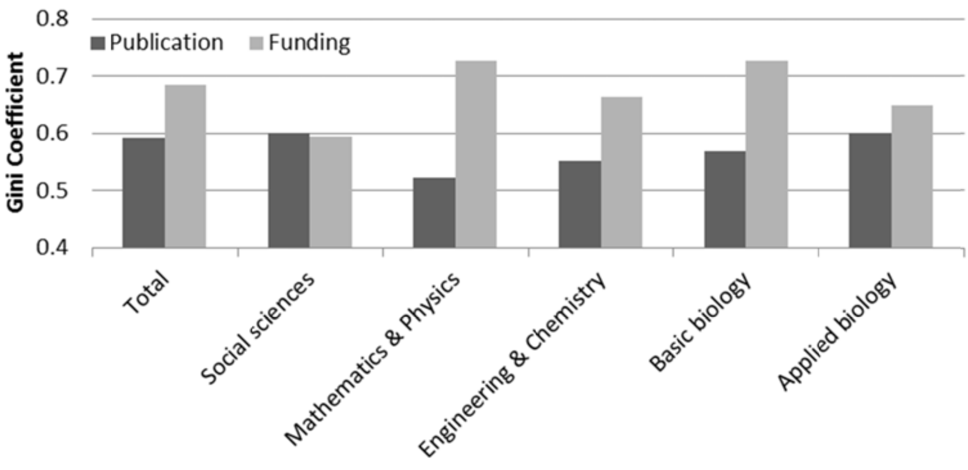
[21] For validation, I counted the number of publications whose affiliation includes each national university using Web of Science, which resulted in a similar level of Gini coefficient.

Figure 6 Comparison of inequality between output and input [22]

(A) Lorenz curve for the publication and grant share of individual researchers



(B) Gini coefficients by field



[22] For full and associate professors in all universities, the distributions of funding and publications in 2001-2005 are illustrated. I counted the number of publications resulting from the grants, and summed them up for each PI. When more than one PI is assigned to one grant, the number of publications is divided by the number of PIs (but this does not change the Gini coefficients substantially).

6. Discussion

Using a Japanese grant database, this study examines the distribution of research funds from several perspectives. First, the data indicates high inequality at the university level (0.919 for all universities and 0.760 for national universities) and that the extent of inequality has not been largely changed over the last four decades (1965-2005). In Japanese universities, the number of faculty members is already highly unequal (e.g., the Gini coefficient in 2005 was 0.602), to which the inequality of funding is partly attributable. In this sense, the high inequality of funding itself may need to be carefully interpreted. In addition, I examined the distribution of publications and found that the publication distribution is less unequal than the funding distribution. This seems to imply an overconcentration of funding in limited universities.

Next, this study examines the individual-level inequality. The data shows that individual-level funding inequality is slightly moderate compared to the university level. During the last four decades, the funding inequality has been more or less stable. The slightly decreasing inequality in recent years may be attributable to the government's recent effort to suppress excessive inequality. To disentangle the causes of inequality, this study analyzes the transition of funding distribution from several perspectives. In the past 40 years, the total budget for the grant has increased by 20 times (after controlling the price level) and the number of grants has increased by 6 times. Simultaneously, the size of academia has increased by 2-3 times in terms of the number of universities or faculty members. One clear feature of funding policy in this period was an inclination to favor larger grants. Especially, after the 1990s, the large-size grants (10 million JPY or greater) have accounted for about 20% of the total budget. Since excessively large grants have been criticized for presumable inefficiency, the relation between grant size and the productivity of grantees should be further investigated. In addition, this study examines multiple awarding (i.e., one researcher receives more than one grant simultaneously). The data shows that 16% of full and associate professors played the PI role in two or more projects in 2005. Considering different objectives of different grant types, multiple awarding may remain to exist to some extent. Nevertheless, it can be inefficient to simultaneously receive many grants and put limited efforts into each granted project. This possibility should be thoroughly studied in future research. Next, the difference of funding inequality across scientific fields is examined. The data suggests that natural sciences have greater inequality than social sciences and that basic research has greater inequality than applied research. The transition of inequality over career stages is also examined with cohorts being controlled. As expected, the data shows higher inequality in senior stages than in junior stages, implying that the success at the earlier career determines future research input. This tendency holds in all fields and in all cohorts. A few features in a specific field are indicated. For example, in social sciences, the inequality at the beginning of a career is fairly low but rapidly rises to its maximum. In mathematics and physics, the inequality is relatively high from the beginning of a career. In basic biology, the inequality at the junior stage decreased from the 1970s to the 1980s, seemingly favoring more equal chance for young scholars. Finally, the funding distribution is compared with the publication distribution. The results indicate greater inequality in funding than in publications in all fields except for social sciences. Although some literature has suggested that funding distribution may well be unequal in accordance with the inequality of output (Hicks and Katz, 2009), this study seems to indicate a potential overconcentration of funding.

This study explores the inequality of research funds from several perspectives, but it entails some limitations that future research should address. First, this study depends only on GIA, one system of research funds. GIA is absolutely the largest and most fundamental funding system in Japan, but university researchers can raise funds from other governmental agencies, industry, and their university. Future research should consider these other sources of budget. Second, the definition of "researcher" and "research universities" are not clear, so Gini coefficients can vary depending on the selected population of researchers or universities. At the university level, many national universities are research-intensive and many private universities are education-oriented, whereas there are universities where some professors engage in research and others do not. Thus, it is controversial which universities should be included in the analyses. At the individual level as well, it is not easy to identify faculty members who actually do research. The first assumption I used in this study, that "researchers" are supposed to obtain at least one grant from GIA in a certain term," may not be far from the truth, but it can exclude some actual researchers. The second assumption, that all faculty members in the top seven universities are researchers, is also nearly the case. However, the cost of ignoring other many universities is not negligible, and we still have to be careful that there are non-researchers even in the top universities. Third, in the argument of efficient funding, the final section of this paper considering both input and output is of greater interest, but the analysis in this study is only preliminary. Future research should look into the causality between funding and science production. In fact, the effect of funding has been yet examined by a limited number of studies (e.g., Crespi and Geuna, 2008). Thus, I expect that the GIA database I developed in this study can contribute to this line of research. With the database, for example, the influence of excessively large grants and multiple awarding can be examined in a more rigorous manner. Moreover, various information offered by the database, such as collaborator, affiliation, and scientific field, coupled with the data of funding and publication, could open an avenue to various research subjects in the economics of science.

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